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(54) Ultrasonic cleaning

(57) Hydrocarbon solvent materials having a relatively high flash point and susceptible to mist formation and regarded as poor for cavitation can be used for ultrasonic cleaning by immersing an object in the solvent 11 in a first tank 10, providing a volume of water 12 in intimate contact with a wall 14 of the first tank 10, and generating ultrasonic acoustic energy within or transmitted to said volume of water to create acoustic coupling at the liquid/solid interface. Preferably, a heat pump (24) is used to heat the solvent (11) and maintain it at a safe temperature, below the flash point. As shown, a transducer 20 transmits ultrasonic acoustic energy to the flow of water maintained by a weir 22 in good acoustic coupling at the wall interface 14 which has a 4° slope to shift air bubbles. A four-stage cleaning system could have a cleaning stage followed by two rinsing and a drying stage.

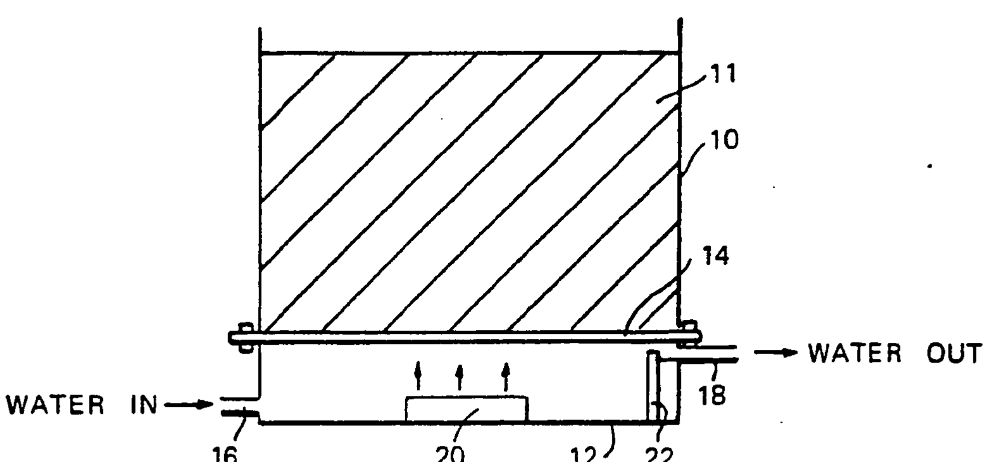

FIG. 1

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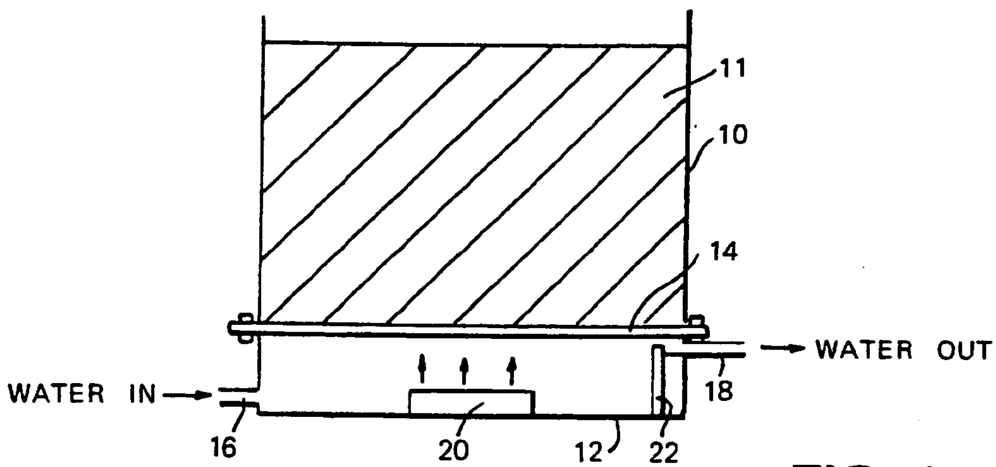

FIG. 1

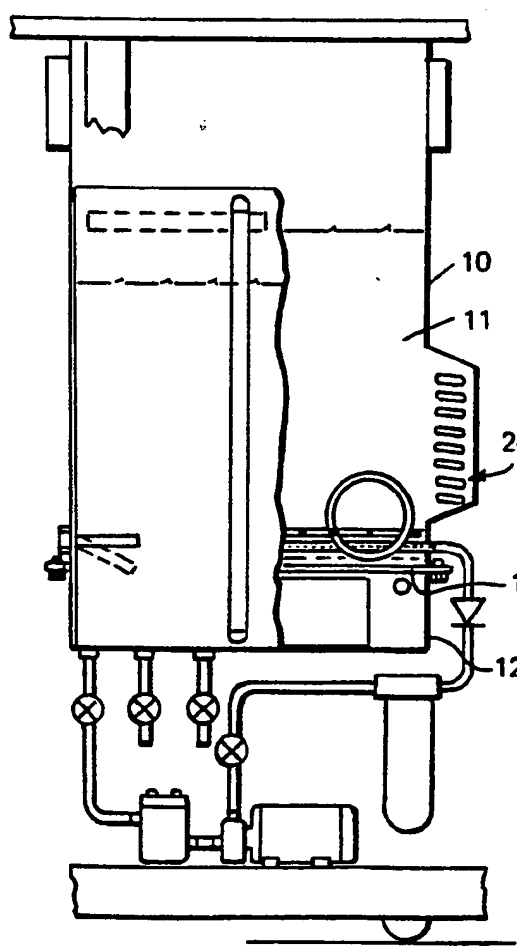

FIG. 2

ULTRASONIC METHODS AND APPARATUS

This invention relates generally to ultrasonic cleaning methods and apparatus.

The principal mechanism in ultrasonic cleaning is cavitation. This is an effect achieved by alternately compressing and relaxing a liquid, which results in a combination of the gas particles suspended within the liquid. The intense disruptive forces created are used to remove contamination from the body to be cleaned. The intensity of the cavitation depends inter alia upon the liquid temperature, the liquid viscosity, the liquid surface tension, the intensity of the ultrasonic vibrations and the frequency of the ultrasonic vibrations.

In ultrasonic cleaning systems it has been conventional to use cleaning agents such as Freon (Registered Trade Mark) and other fluorocarbons. Cleaning agents such as this have no flash point and are therefore not hazardous from the point of view of flammability. However, these products have now been established to be hazardous to the ozone layer and the use of alternative materials is to be preferred.

Various hydrocarbon materials are known for use in semi-aqueous cleaning processes. However, such hydrocarbon products have a flash point which is typically of the order of 159°F. They are also susceptible to mist formation, which means that the materials have to be treated as combustible liquids. Therefore, if such hydrocarbon materials are used in an ultrasonic cleaning system, it has heretofore been necessary to provide a blanket of inert gas above the hydrocarbon material in the cleaning tank, or alternatively to adopt other costly measures to ensure that th process is not hazardous.

Additionally, such hydrocarbon solvents typically have a very low vapour pressure, a relatively

high viscosity and a very high surface tension. These three latter characteristics all adversely affect cavitation, and therefore such hydrocarbon materials would on the face of it be regarded as poor for use in an immersion bath where one is seeking to create cavitation. This is in addition to the problems generated by the need to operate below the flash point and to prevent mist formation.

It is an object of the present invention to provide ultrasonic cleaning methods and apparatus based upon the use of cleaning agents which do not deplete or damage the ozone layer in the atmosphere.

In accordance with the present invention it has been discovered that it is possible to use hydrocarbon materials as aforementioned for ultrasonic cleaning purposes with high efficiency, in spite of those materials apparently being poor for cavitation and difficult to use without expensive auxiliary equipment.

It is to be understood that the present invention is applicable to the use of a wide range of solvents which, on the face of it, are poor for cavitation, especially hydrocarbon materials, including terpenes and terpene derivatives. One particular material which is capable of being used in the method and apparatus of the present invention is the hydrocarbon material produced by Du Pont under the reference KCD-9438. However, it is to be understood that the present invention is not in any way limited to this particular material, which is referred to by way of example only. The hydrocarbon material KCD-9438 has a flash point of 159°F, a vapour pressure of 0.2 mm Hg at 20°C, a viscosity of 1.4 cp at 25°C and a surface tension of 28 dyn s/cm at 25°C. These are all properties which would cause a person looking to find a

new utilisable material to dismiss such hydrocarbon materials as being poor for cavitation, and difficult to use without hazard.

In accordance with the present invention there is provided a method of cleaning objects by the use of ultrasonic cavitation which comprises immersing an object in a liquid solvent material which is poor for cavitation within a tank or chamber, providing a volume of water in intimate contact with a wall of said tank or chamber, and generating acoustic energy within or transmitted to the said volume of water, in such a manner as to create acoustic coupling at the interface between the water and the said wall of the tank or chamber.

Preferably, the method also includes using a heat pump in association with the tank or chamber holding the solvent material, in order to be able to ensure that the solvent material does not exceed a predetermined safe temperature.

Also in accordance with the present invention there is provided ultrasonic cleaning apparatus comprising a first tank or chamber arranged to hold a liquid solvent material which is poor for cavitation, a second tank or chamber adjacent to said first tank or chamber with a common solid interface therebetween, means to supply water to fill said second tank or chamber, and means within or outside said second tank or chamber arranged to generate acoustic energy within the volume of water in said second tank or chamber for acoustic coupling at the liquid/solid interface.

Preferably, associated with the first tank or chamber is a heat pump which will prevent the temperatur of the solvent material within this tank or chamber from rising above a predetermined level without the use of any electrical heating elements.

Preferably, a flow of water through the second tank or chamber is provided.

In a preferred embodiment of the invention, with a transducer within the second tank or chamber, a weir is provided within the second tank or chamber to stabilise the movement of the water within the tank or chamber and to generate a laminar flow across the whole width of the transducer.

In order that the invention may be fully understood, one presently preferred embodiment will now be described by way of example and with reference to the accompanying drawings, in which:

Fig. 1 is a block schematic diagram of one form of apparatus in accordance with the invention; and,

Fig. 2 is a diagram showing more details of the apparatus and in particular illustrating the use of a heat pump.

As shown in the drawings, the ultrasonic cleaning apparatus of the present invention comprises a rectangular cross-section tank or chamber 10 which is arranged to contain a solvent cleaning material 11, especially a hydrocarbon material such as KCD-9438 referred to above. Bolted or otherwise secured to the bottom of the tank 10 is a second rectangular cross-section tank or chamber 12. The dividing wall 14 between the two tanks may be in the form of a thin planar solid stainless steel screen for example. The lower tank 12 has an inlet 16 for water and an outlet 18. A transducer 20 which transmits ultrasonic acoustic energy is shown mounted within the lower tank 12, although it could alternatively be mounted on the outside of that tank, or in any other manner which gives a good generation of acoustic energy within the water in the tank. The electrical leads to the

transducer 20 and the associated generator and electrical circuitry are not shown, being well-known per se. Within the tank 12 adjacent to the outlet 18 is positioned a cross-weir 22 which extends across the full width of the tank. The provision of the cross weir 22 across the full width of the tank means that when the second tank 12 is filled to the dividing wall 14 with water one creates full width overflow across the weir and also generates a laminar flow of water across the whole width of the transducer 20 rather than a turbulent flow.

Preferably, the dividing screen or wall 14 is inclined at a very shallow angle to the horizontal, for example of the order of 4°, sloping upwards from the tank inlet end to the tank outlet end, so that any bubbles of air which form within the water tank 12 do not accumulate below the dividing wall 14, and especially above the transducer, but will move towards the weir 22 and there be removed from the tank 12. This ensures that there is good acoustic coupling at the liquid/solid, i.e. water/screen, interface, namely monomolecular coupling.

Although a flow of water through the second tank 12 is preferred, one could alternatively have a static volume of water below the dividing wall 14 into which the ultrasonic energy is generated.

Fig. 2 shows a similar arrangement, but also includes a heat pump 24 which avoids the need for any electrical heating of the solvent material 11, thus reducing any hazard, and which enables the solvent material to be kept at a predetermined, safe temperature level, for example of the order of 55°C (130°F). This temperature is chosen so that the temperatur of the solv nt mat rial cannot rise to a level which will generate mist. Th heat pump 24 may

be of the type described in UK patent specification GB 1573553 for example, the disclosure of which is incorporated herein by reference.

The ultrasonic cleaning apparatus described above may be part of a multi-stage cleaning system or may be operated as a stand-alone unit. In the case of a four-stage system this could consist of a cleaning stage, a first rinse stage, a second rinse stage and a drying stage.

CLAIMS:

1. Method of cleaning objects by the use of ultrasonic cavitation which comprises immersing an object in a liquid solvent material within a tank or chamber, providing a volume of water in intimate contact with a wall of said tank or chamber, and generating acoustic energy within or transmitted to the said volume of water, in such a manner as to create acoustic coupling at the interface between the water and the said wall of the tank or chamber.

2. A method as claimed in claim 1, in which the object is immersed in a hydrocarbon solvent material.

3. A method as claimed in claim 2, in which the hydrocarbon solvent material has a flash point of the order of 159°F.

4. A method as claimed in claim 2 or 3, in which the hydrocarbon solvent material is a terpene or terpene derivative.

5. A method as claimed in any preceding claim, which includes creating a controlled laminar flow of water over and across an ultrasonic transducer positioned within said volume of water.

6. A method as claimed in claim 5, which includes directing said flow of water over a weir positioned within a tank or chamber holding said volume of water.

7. A method as claimed in any preceding claim, which includes using a heat pump in association with the tank or chamber holding the solvent material for the controlled heating of said solvent material.

8. A method as claimed in claim 7, which includes operating the heat pump so as to maintain the solvent material at a temperature f the order of 130°F.

9. Ultrasonic cleaning apparatus comprising a first tank or chamber arranged to hold a liquid solvent material, a second tank or chamber adjacent to said first tank or chamber with a common solid interface therebetween, means to supply water to fill said second tank or chamber, and means within or outside said second tank or chamber arranged to generate acoustic energy within the volume of water in said second tank or chamber for acoustic coupling at the liquid/solid interface.

10. Apparatus as claimed in claim 9, wherein the first tank or chamber holds a hydrocarbon solvent material.

11. Apparatus as claimed in claim 10, wherein the hydrocarbon solvent material has a flash point of the order of 159°F.

12. Apparatus as claimed in claim 10 or 11, in which the hydrocarbon solvent material is a terpene or terpene derivative.

13. Apparatus as claimed in any of claims 9 to 12, which includes within the second tank or chamber an ultrasonic transducer and means to create a controlled laminar flow of water over the transducer.

14. Apparatus as claimed in claim 13, wherein said means to create a controlled laminar flow of water comprises a weir.

15. Apparatus as claimed in any of claims 9 to 14, wherein said solid interface comprises a planar sheet of material inclined at a shallow angle to the horizontal.

16. Apparatus as claimed in claim 15, wherein the planar sheet is of stainless steel and is inclined at an angle of the order of 4° to the horizontal.

17. Apparatus as claimed in claim 9 to 16, including a heat pump in association with said first

tank or chamber for the controlled heating of the solvent material.

18. A method of cleaning objects substantially as hereinbefore described with reference to the accompanying drawings.

19. Ultrasonic cleaning apparatus substantially as hereinbefore described with reference to the accompanying drawings.

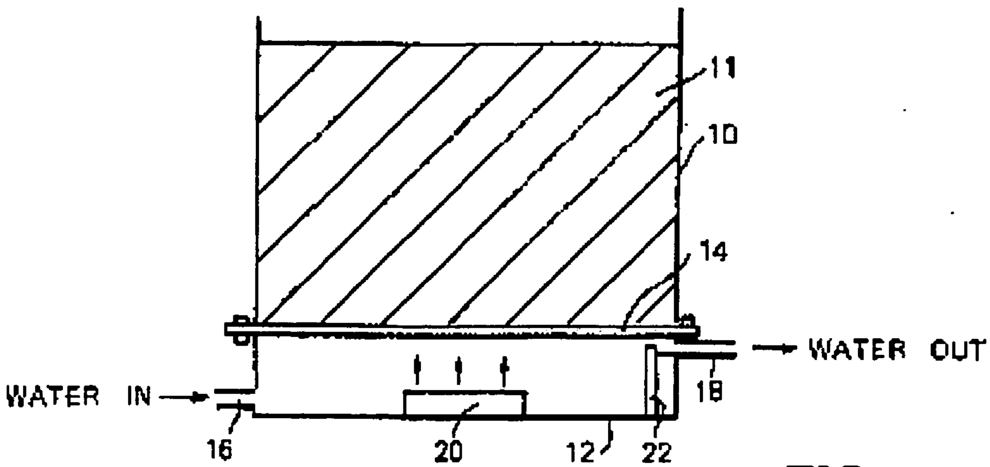

FIG. 1

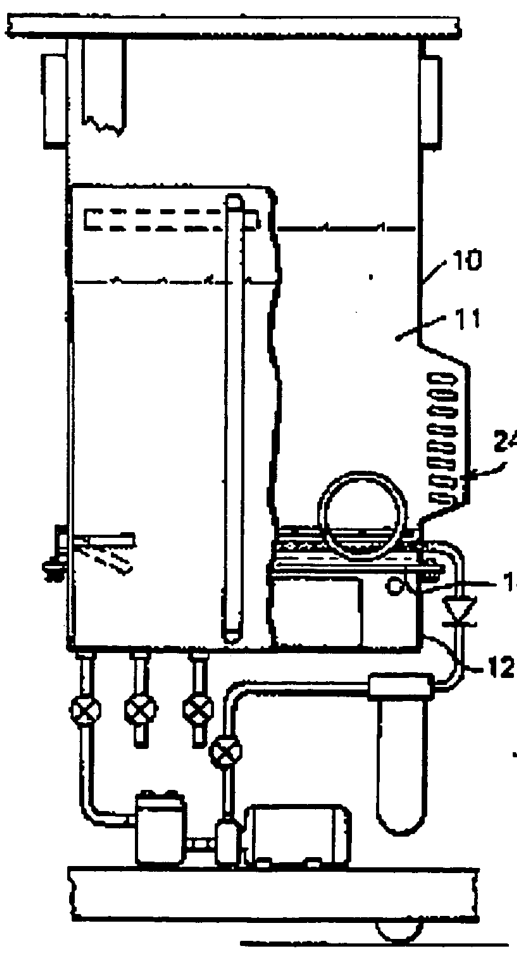

FIG. 2